USING OPTIMIZED COMPUTER SIMULATION TO FACILITATE THE LEARNING PROCESS OF THE FREE THROW IN WHEELCHAIR BASKETBALL

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ABSTRACT

USING OPTIMIZED COMPUTER SIMULATION TO FACILITATE THE LEARNING OF THE FREE THROW IN WHEELCHAIR BASKETBALL

A computer simulation program was previously developed by the researcher which determines a theoretically optimal movement pattern for the free throw in wheelchair basketball. The purpose of this study was to evaluate the external validity of the optimization program by examining whether the knowledge of the optimal movement pattern facilitates performance of the free throw in wheelchair basketball.

In a pilot study, four able-bodied players from the Saskatchewan Wheelchair Basketball Men's Team were invited to participate on one occasion. These participants were videotaped shooting free throws to provide knowledge of an expert wheelchair free throw movement pattern. Using video analysis, it was found that the release conditions used by this group were very similar to those predicted to be optimal. This lent support to the predicted optimal movement pattern being an actual optimal movement pattern for the free throw in wheelchair basketball.

In the primary study, thirty-three able-bodied male participants were randomly assigned to three groups: a no-feedback group; a video-feedback group; and an optimal pattern feedback group. The participants performed wheelchair basketball free throw training for three days over one week. The no-feedback group simply shot free throws from a wheelchair, whereas the video-feedback group viewed video of their previous free throws, and the optimal pattern group viewed video of their previous free throws

with an optimal free throw pattern superimposed. The participants also completed a pretest one week before and a retention test one week after the training period.

A repeated measures ANOVA was used to test for significant differences between the three training groups in free throw success in wheelchair basketball over each testing occasion. The statistical analyses indicated that there were no differences in free throw success between the group that had knowledge of their personalized optimal movement pattern when compared to the groups that received either no-feedback or video-feedback ($p<0.05$).

Video analysis revealed that the wheelchair free throw movement pattern of participants in the optimal pattern group changed substantially from the pretest to the post-test. This suggests that the participants in the optimal pattern group were making progress towards their optimal movement patterns, but had not yet mastered the movement pattern.

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DEDICATION

This thesis is dedicated to my wonderful husband, Trent. Without his inspiration, emotional support, and manual labor, none of this would have been possible. Trent took many hours off from his own thesis work to come to the gym and help out as my equipment manager and ball boy. He was also my main recruiter, and convinced most of his friends and colleagues to participate in my study. Thanks Trent, for your unending love and support.

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1.1 INTRODUCTION

The enjoyment we derive from participating in a sport is enhanced by improving our competence in that sport (Whiddon & Reynolds, 1983). In order to be successful in a sport, one must become proficient in the fundamental skills of the game (Malone, Nielson, & Steadward, 2000). Many studies have addressed the optimal patterns for sport skills in order to increase this competence in athletes. However, the area of wheelchair sport has been overlooked. Currently, there are few published studies which have attempted to optimize skills in wheelchair sport (Goosey-Tolfrey, Butterworth, & Morris, 2002).

Wheelchair basketball is regarded as one of the highest profile disability sports (Goosey-Tolfrey et al., 2002). One fundamental skill in need of development by wheelchair basketball players is free throw shooting. Wheelchair basketball players have been consistently found to have free-throw shooting percentages approximately 20% lower than that of standing players of a similar caliber (Kozar, Vaughn, Whitfield, Lord, & Dye, 1994). There are substantial disadvantages to shooting the basketball from a lower position (Owen, 1982), however this disadvantage cannot explain the extent of the difference in free throw shooting success between wheelchair and standing basketball players. According to Brancazio (1981), a person's performance on the basketball court can be improved through the study and application of kinematics and Newtonian mechanics.

Computer simulations of human movement can be used to lend insight into the mechanics of a movement or to make predictions about a hypothetically optimal movement pattern (Yeadon & King, 2002). For a computer model to give any insight into an actual movement, the model must be an appropriate representation of the system being modeled. In addition, extraneous factors that may not have been considered in the computer simulation may have an effect on the actual performance of the skill. Thus, the predicted theoretical optimal movement pattern may not be truly optimal in real life. Therefore, it is necessary to test the results predicted from a computer optimization to determine if they are applicable in a real world situation.

A computer optimization which determines a theoretically optimal movement pattern for the free throw in wheelchair basketball has been developed (Schwark, Mackenzie, & Sprigings, 2004). The optimization can be personalized to the body size and dimensions of any individual in order to determine their own personal optimal wheelchair free throw movement pattern. This optimization program could potentially be used as a guide for wheelchair basketball coaches to teach wheelchair basketball players how to improve their free throw shooting abilities. However, there is no proof that the program actually helps to improve free throw shooting. Therefore, the purpose of this study was to evaluate the external validity of the optimization program by examining whether the knowledge of the optimal movement pattern facilitates performance of the free throw in wheelchair basketball.

1.2 LITERATURE REVIEW

1.2.1 Wheelchair Basketball

Wheelchair basketball was founded shortly after World War II as a rehabilitation exercise for injured veterans (Malone et al., 2000). Today, wheelchair basketball is one of the most popular of wheelchair sports, and is played competitively in over 75 nations (Malone et al., 2000; Goosey-Tolfrey et al., 2002). The rules of the game are the same as the traditional basketball game except for modifications to allow for the use of wheelchairs (Owen, 1982). For example, a traveling violation occurs when a player makes more than two thrusts of the wheels, rather than two steps, without dribbling the ball, and a technical foul can be called if a player raises his buttocks off the chair.

Players are looking to optimize their skills in the game of wheelchair basketball since the aspect of competition has been introduced. Also, as the popularity of wheelchair sports increases, new players will need to learn the necessary skills of the game. According to Brancazio (1981), a person's performance on the basketball court can be improved through the study and application of kinematics and Newtonian mechanics. The knowledge of an optimal free throw movement pattern could help to improve the skills of current players, and shorten the acquisition time by facilitating learning of the skill in new players. Many studies have addressed the optimal patterns for sport skills in order to increase competence in athletes. However, the area of wheelchair sport has been greatly overlooked. Currently, there are few studies that attempt to optimize skills in wheelchair sports, including wheelchair basketball (Goosey-Tolfrey et al., 2002). It is important that people who use wheelchairs are provided the same opportunities to develop skills and excel in sports.

1.2.2 The Free Throw

To be successful in wheelchair basketball, players must develop the fundamental skills of the game (Malone, Gervais, & Steadward, 2002; Schwark et al., 2004). One fundamental skill in need of development by wheelchair basketball players is free throw shooting. A free throw is a privilege given to a player that has been fouled by another player. The fouled player is given the opportunity to score one point by an unhindered shot for a goal from a position directly behind the free throw line (F.I.B.A., 1980). The free throw should be the easiest shot in basketball since it is not contested. The free throw is classified as a closed, discrete skill as it is performed in a stable, predictable environment with definite start and end points (Malone et al., 2000). Despite this stability, many players struggle with free throw shooting (Vancil, 1996).

Wheelchair basketball players have consistently been found to have free throw shooting percentages that are approximately 20% lower that their standing counterparts (Owen, 1982; Kozar et al, 1994). At the 1994 Men's World Championships, male standing basketball players had free throw shooting percentages ranging from 59-83%, with a mean of 71%, whereas male wheelchair basketball players at the 1992 Paralympic Games had percentages ranging from 35-54%, with a mean of 41% (Malone et al., 2000).

This low free throw shooting percentage can be very costly to a team, as free throws are often the deciding factor in the outcome of a basketball game (Kozar et al., 1994; Malone et al., 2002). In a study by Kozar et al. (1994), they found that free throws account for approximately 20% of the total points in a NCAA Division I men's basketball game. They also found that winning teams scored a significantly higher percentage of their total points from free throws than the losing teams. Thus, it seems that increasing players' proficiency in the skill of free throw shooting may help lead their teams to victory.

It is not unexpected that wheelchair basketball players should have a lower free throw shooting percentage than that of standing players. There are substantial disadvantages to shooting the basketball from a lower position (Owen, 1982). As the height of release of the ball decreases, the margin for error in release angle also decreases (Brancazio, 1981). Thus, when the ball is released from a lower position, the shooter must be more accurate in the release angle that is used in order to make a successful basket. Also, in the wheelchair free throw, the propulsive forces must come mainly from the arms and upper body with no help from the legs, as a standing player would have (Malone et al., 2002). As the arm muscles are much smaller than the leg muscles, it is much more difficult to generate the necessary forces to shoot a free throw. However, several wheelchair basketball players have been shown to have shooting averages greater than 70% (Owen, 1982). This shows that with proper technique and practice, players in wheelchair basketball can achieve high free throw shooting percentages.

Malone et al. (2000) found that the majority of missed wheelchair free throws fell short of the basket, indicating insufficient force or trajectory to reach the target. Goosey-Tolfrey et al. (2002) identified important factors affecting wheelchair free throw success to be personal mechanics, arm strength, and trunk stability. Personal mechanics would generally lead to a short shot if the athlete released the ball with too low a speed or angle. A lack of arm strength would lead to a shot falling short if the athlete was not able to generate enough force to release the ball with a high enough speed. A lack of trunk stability causes the shoulder to be positioned lower and thus, the ball is released from a lower position. With a greater distance to travel, the ball must be released with a greater speed. A lack of trunk stability will also make it more difficult to generate force at the shoulder, even with adequate arm strength, as the shoulder is not held in a stable position.

The release angle and release velocity for a wheelchair free throw should differ significantly from that found to be optimal for standing players since wheelchair free throws are performed from a lower shooting position (Malone et al., 2002). A successful free throw attempt made by a wheelchair basketball player will require both a greater release angle and a greater release speed than a free throw taken by a standing player. Goosey-Tolfrey et al. (2002) found that male wheelchair basketball players used release angles between 54^{o} and 64^{o}, as measured from the horizontal, and release velocities between 7.0 to 8.2 m/s. Hay (1993) found the optimal release angle and release speed for standing male basketball players who released the ball from a height of 2.13 m to be 50.68^{o} and 7.398 m/s, respectively. In a previous computer optimization by the author (Schwark et al., 2004), a release angle of 53.8^{o} and a release speed of 7.4 m/s were found to be the optimal release conditions for a hypothetical subject shooting free throws from a wheelchair (Figure 1.1).

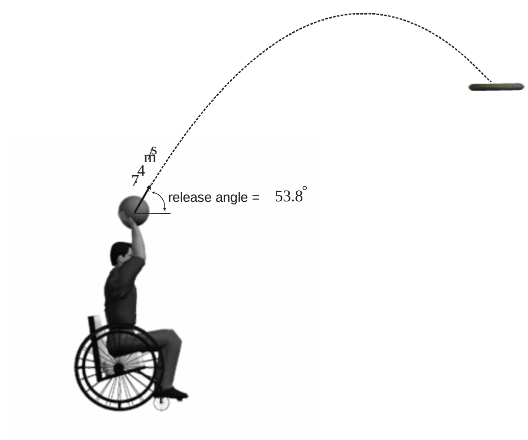


Figure 1.1. Optimal release conditions for a wheelchair basketball free throw calculated by Schwark et al. (2004).

1.2.3 Classification System for Wheelchair Basketball Players

In the sport of wheelchair basketball there is great variation in the ability of the players. In 1984, the International Wheelchair Basketball Federation (IWBF) developed a classification system to provide an opportunity for players at all levels of physical potential to participate in wheelchair basketball (Malone et al., 2002). The current system divides players into 8 classes (class 1.0, 1.5, 2.0, 2.5, 3.0, 3.5, 4.0, 4.5) based on trunk movement and sitting balance (Lachance, 2005). Players in class 1.0 are not able to perform active rotation of the torso and lack abdominal muscles. Players in class 2.0 can perform active rotation of the torso and have active trunk stability however they cannot fix their pelvis or move their torso in the frontal and sagittal planes. Players in class 3.0 have mobility in the frontal plane and therefore lean forward and return to an upright position. Players in class 4.0 have active mobility in the frontal and sagittal planes and can therefore lean forward and to the sides and return to an upright position. Half point classes were added for cases in which a player has too much functional ability for the lower class, but not enough for the higher class. Within this system, each player is designated a point value and the total point value of the five players on the court cannot exceed 14 points. This classification system is utilized by the Canadian Wheelchair Basketball Association (CWBA) with a few modifications. In Canada, a 0.5 class has been added for quadriplegics, and people who do not have any relevant physical disability can play as a 4.5 point player however, they will not be able to play internationally (Lachance, n.d).

Malone et al. (2002) conducted a study in which the shooting mechanics of wheelchair basketball players were examined in players of varying classes. They found that the free throw shooting pattern of players in classes 1 and 2 differed significantly from that of players in classes 3 and 4. Players in classes 3 and 4 tended to use a higher point of release, as they have the ability to reach the arms upward without losing trunk stability. They also have the ability to move their trunk forcefully in the direction of the shot. Players in classes 1 and 2 have a significant loss of stability in the trunk as the shooting arm is extended over the head (Malone et al., 2002). The specific movement pattern for the free throw that is being studied consists of movements at the shoulder, elbow and wrist joints, with the shoulder at a stationary position. Thus, the movement pattern assumes adequate trunk stability and upper body strength, and applies only to players classified as 3-4.5.

1.2.4 Computer Simulation

Computer simulations of human movement are often used to lend insight into the mechanics of a movement (Yeadon & King, 2002). Hatze (1973), a pioneer in computer simulations for biomechanics research, used a mathematical model to simulate a kicking motion. The goal of his optimization was to find the kicking movement pattern that would minimize the time necessary to kick a target. With the knowledge of this optimal movement pattern for the upper leg, lower leg, and foot, Hatze (1973) developed a video demonstrating this movement pattern, and superimposed it over video of a subject's kicking movement pattern. This video feedback helped the participant to adopt a near optimal kicking movement pattern and decrease the amount of time it took for him to kick the target.

Another early study in the area of computer simulation was conducted by Miller (1973) on springboard dives. She constructed a four segment model of a diver, consisting of a head and trunk segment, legs, right arm, and left arm to simulate the free-fall phase of a nontwisting dive in the pike and layout positions. Miller (1973) used this computer simulation to examine the influence of different body proportions, such as height, weight, and moments of inertia, upon a dive. She also examined how the performance of a dive would be affected when using differing patterns of lateral arm displacement.

In recent years, a number of computer simulations of skills in sports, such as diving, gymnastics, rowing, golf, track and field, basketball, soccer, baseball, and volleyball have been conducted. Sprigings, Lanovaz, Watson, and Russell (1998) developed a simulation of a four segmented model of a gymnast performing a backward giant circle from handstand to handstand. In this event, the gymnast must swing from one held handstand position to another. The model consisted of a cables-rings segment and a three-segment gymnast's body comprising arms, head-torso, and legs. The goal of the optimization was to minimize the gymnast's swing during the held handstand position. Holvoet, Lacoutre, Duboy, Junqua, and Bessonnet (2002) developed a simulation of an eight segmented model of a gymnast performing giant swings on the high bar. They examined the joint forces and moments involved in a series of large circling motions concluding in a "tkatchev" release-regrasp skill. Bray and Kerwin (2003) developed a mathematical model of a soccer ball's flight incorporating aerodynamic lift and drag forces to explore the direct free kick with sidespin in soccer. They used video analysis to calculate the lift and drag forces acting on the soccer ball, and then used this knowledge to realistically model the free kick in soccer. Recently, Wilson, Yeadon, and King (2004) developed a computer simulation of an eight segmented model to examine high jumping and long jumping performances. They optimized jumps for height and distance by maximizing height and distance, respectively.

While there is a plethora of research on optimizations of sports skills, the area of wheelchair sport has been greatly overlooked. Currently, there are few studies that attempt to optimize skills in wheelchair sports, including wheelchair basketball (Goosey-Tolfrey et al., 2002). According to Malone et al. (2002), for wheelchair basketball players to reach their free throw shooting potential, it is necessary to understand the mechanics of the movement. Computer optimizations could be used to attain this insight into the mechanics of a movement (Yeadon & King, 2002), such as the free throw in wheelchair basketball.

Wheelchair basketball players must also be able to consistently reproduce the release speed and angle that will result in a successful free throw. From the free throw line, there are numerous different combinations of release speed and angle that will project the ball to the center of the basket (Brancazio, 1981). However, as the ball is smaller than the basket, the ball does not need to go through the center of the basket to result in a successful shot. At a given release angle, if the shot is released at a slightly lower speed, it may touch the front rim and still go in. If released at a slightly higher speed, the ball may touch the back rim and result in a successful basket. Brancazio (1981) refers to this as the margin for error in speed. Accordingly, for a given release speed there is a range of release angles that will result in a successful basket, known as the margin for error in angle. Brancazio (1981) used closed form mathematical formulation based on Newton's laws to examine the sensitivity of the margins for error in release speed and angle. His findings indicate that controlling the speed of release was an order of magnitude more important than was controlling the angle of release in terms of making a successful basket. Brancazio (1981) concluded that the lowest release speed capable of producing a successful basket would result in both the optimal release conditions, and the easiest movement pattern for players to reproduce consistently.

Using this premise, a computer optimization to find the optimal movement pattern for the free throw in wheelchair basketball was developed by Schwark et al. (2004). The search for the optimal release conditions for the ball involved a two-step process. The first step was to develop a method that would compute, for a given distance from the basket, the optimal speed and angle of release of the ball. The second step was to determine the optimal arm motion that would generate this optimal ball speed and release angle for a successful basket. Computationally, this required two separate optimization loops running within the same program. The outer optimization loop was programmed such that at the moment of ball release, the instantaneous vertical and horizontal distances of the ball from the centre of the basket were calculated. This distance information was then passed to the inner optimization loop subroutine, which in turn computed the optimal trajectory using Powell's optimization search (Press, Teukolsky, Vetterling, & Flannery, 1992) with Brancazio's minimum release speed as the objective function.

The corresponding optimal vertical and horizontal components of velocity computed by this subroutine were then passed back to the outer loop program for comparison with the actual vertical and horizontal components of the ball's speed at release. This difference was minimized in the outer loop using a second Powell subroutine. In both the inner and outer optimization searches, the sums of accrued penalty variables were included in the objective function to discourage searches in unrealistic directions. Thus, the outer optimization loop controlled the arm movement pattern up to the point of release, and the inner optimization loop determined the optimal speed and angle of release at the point of release.

The optimization scheme for the inner loop was selected according to the approach used by Brancazio (1981). This method required that the height and horizontal distance to the basket at release be known. The release angle was used as a control variable, and the corresponding release velocity that would project the ball to the coordinates of the centre of the basket was calculated. The lowest release speed that would produce a successful basket without hitting the rim was used as the objective function.

The outer computational loop was designed to determine the optimal movement pattern of the arm segments that would produce the optimal release speed and angle of projection for the ball. In this simulation study it was assumed that the athlete being modeled was classified as 3 to 4.5 on the international classification system (International Wheelchair Basketball Federation Player Classification Commission, 2004) and thus could provide adequate trunk stability during the free throw. With this understanding, the shoulder joint was fixed and the segments of the right arm moved in relation to this origin. The right arm of the wheelchair athlete, holding a basketball, was modeled as a 2-D, three-segment linked system comprising the upper arm, forearm, and hand+ball (Figure 1.2). The left arm was not included in the model since it was assumed to make no contribution to the propulsion of the ball, and that any directional stability it does provide would be easily handled through the 2-D constraint placed on the model.

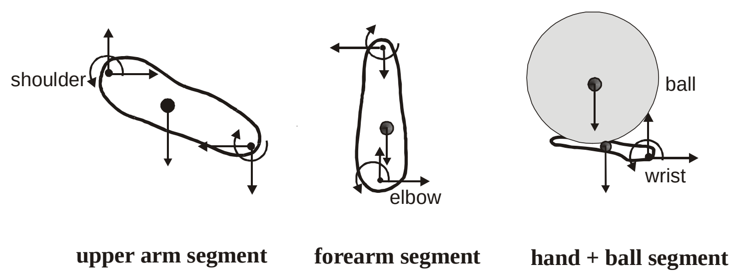


Figure 1.2. Two-dimensional model, with muscle torque generators inserted at the shoulder, elbow, and wrist, used in simulating the wheelchair free throw.

Torque actuators for the right arm were inserted at the proximal end of each segment and gave the model the ability to add energy to the system. The torque actuators used in the simulation were programmed to be constrained by the activation rate and force-velocity properties of human muscle (Sprigings & Neal, 2000). The force-length property of muscle was expected to play a second order role in the outcome of the performance (Caldwell, 1995) and, as such, was not included in the simulation model. Parameter values for segment length, moment of inertia, and mass for a representative player with a body mass 80 kg, and a standing height of 1.83 m, were calculated using the values of De Leva (1996). The basketball was modeled as a spherical shell with a mass of 0.608 kg and a moment of inertia of 0.00618 $kg \cdot m^2$ (Meriam, 1978).

The equations of motion for the three-segment system were written using a Newtonian formulation in combination with the known equations of constraint for a system linked with revolute joints. The hand + ball segment was treated as a single segment up until the point of release. The moment of inertia of the hand segment was adjusted using the parallel axis theorem to account for the ball's additional inertial contribution. A fifth order Runge-Kutta-Fehlberg algorithm (Burden, Faires, & Reynolds, 1981) with variable step size was used to drive the simulation model (Sprigings, Lanovaz, Watson, & Russell, 1998).

The starting position for the upper arm was constrained at a 60^{o} angle below the horizontal (Figure 1.3). Six control variables were used to regulate the simulated movement pattern of the arm segments: time of onset of the activation for both the elbow and wrist muscle torque actuators (the muscle torque for the shoulder joint was assumed to begin at time zero); the time of release; and the maximum isometric torques used in the equations governing the torque output from each muscle actuator at the three joints. Prior to the dynamic activation of the muscle actuators at the elbow and wrist joints, the relative angles of the forearm and hand segments with respect to the upper arm were constrained to remain constant. Penalty variables were included to discourage searches in unrealistic directions. For example, a penalty would be added if the elbow began to hyperextend beyond the capabilities of a human's elbow. Also, a penalty would be given if the lower arm passed through the upper arm. These and many other penalty variables ensured that the optimization would not find an unrealistic movement pattern to be optimal. The optimization computed the optimal speed and angle of release to be 7.40 m/s and 53.8^{o}, respectively (Figure 1.1).

Figure 1.3. Starting configuration for the 3-segment system.

According to Yeadon and King (2002), in order to place any confidence in the results of a computer simulation, it is necessary to compare the output of the model with an actual performance. If the model is not a good representation of the biomechanical system being studied, then any insight into the mechanics of the model may have little relevance to the biological system being studied (Yeadon & King, 2002). They suggest validating the simulation by personalizing the simulation to individuals and then comparing the simulation results to their actual performances.

The previously developed computer optimization can be personalized to any individual by inputting body segment lengths and inertial parameters of the arms. The arm segment masses and moments of inertia are calculated using percent body weight and body segment lengths reported by de Leva (1996).

1.2.5 Feedback

During skill acquisition, feedback can be used to enhance motor learning by providing both information and motivation to the learner (Hebertt & Landin, 1994; Wulf, Shea, & Matschiner, 1998). Two types of feedback are knowledge of results (KR) and knowledge of performance (KP). Knowledge of results is information about the outcome of a task, whereas knowledge of performance is information about the execution of the movement that produces the outcome (Boyce, 1991; Hebert & Landin, 1994). For example, after a golf swing KR would be telling the golfer where the ball landed without any other information, whereas KP would be providing the golfer with information about the swing, such as hip, shoulder, knee, or head movements.

It has been suggested that KR may be used to calibrate the movement pattern (Salveson, Whiting, & Hoff, 2001; Brisson & Alain, 1996). This means that when people are given KR, they can modify their movement from trial to trial until they find the optimal movement pattern. If this was the case, it could be assumed that individuals who continually practice the skill of free throw shooting will become proficient at the skill. However, when looking at competitive basketball and wheelchair basketball players, this is not the case. A glaring example of this is NBA basketball player Shaquille O'Neal, who reportedly practices at least 50 to 100 free throws a day, yet has a 53.5% career free throw percentage (Bamberger, 1998). It may be necessary to provide more information than just the outcome of the movement. As the movement becomes more complex and an appropriate outcome depends on the interaction of several segments, information about both movement kinematics and kinetics may be more important than KR alone (Mononen, Viitasalo, Konttinen, & Era, 2003; Brisson & Alain, 1997). The free throw in wheelchair basketball requires the coordination of at least three body segments, the upper arm, lower arm, and hand, and so it may be important to provide the learners with KP, in addition to KR.

Knowledge of performance has been shown to have potential learning benefits when the feedback is superimposed over a template pattern (Brisson & Alain, 1997). For example, learning may be enhanced if an optimal movement pattern is superimposed over video of an individual's actual movement pattern. Observing the optimal movement pattern can be thought of as observing an expert model. Observing a model may facilitate the development of appropriate limb and body movements necessary to performing a skill and for developing error correction abilities (Atienza et al., 1998; Hebert & Landin, 1994; Magill & Schoenfelder-Zohdi, 1996; Magill, 1993; Tzetzis et al., 1999; Williams, Alty, & Lees, 2002). The model provides the learners with information on how the skill should be performed, whereas viewing their movement patterns provides the learners with information on their own performances of the skill (Tzetzis et al., 1999; Magill & Schoenfelder-Zohdi, 1996). The combination of these two sources can be beneficial to the learning of a skill by increasing the amount of task related information available, thereby aiding in the development of appropriate memory representations of the skill (Hebert & Landin, 1994; Tzetzis et al., 1999).

One factor that is related to the effectiveness of the use of modeling is the characteristics of the model (Tzetzis et al., 1999). Models that are similar to the participants have been found to be more effective than dissimilar models (George, Feltz, & Chase, 1992; Gould & Weiss, 1981; McCullagh, 1987). Gould and Weiss (1981) found that female university students who observed a female model perceived to be similar in athletic ability demonstrated greater muscular leg endurance than others who observed a male model perceived to be superior in athletic ability. George et al. (1992)

found that nonathletic female university students who observed either a nonathletic female or nonathletic male model performed better on a leg extension task than those who observed either an athletic female or athletic male model. In a study conducted by McCullagh (1987) the same model was used to demonstrate a Bachman ladder task to female university students, however one group observed her as a university student, and the other group observed her as a dancer. The group that observed the university student perceived the model to be more alike and performed better on the Bachman ladder task. George et al. (1992) and Gould and Weiss (1981) found that the participants who observed a model of similar ability and sex were found to have a higher level of self-efficacy, which paralleled performance results. However, McCullagh (1987) found that model similarity did not influence self-efficacy. Thus, it is uncertain as to why model similarity may influence performance.

1.2.6 Feedback Schedules

The efficacy of feedback in the learning of a skill depends greatly on how often the feedback is given, or the feedback schedule. There is currently an argument taking place as to whether less is more. Some argue that giving feedback after every trial leads to the greatest improvement in skill development (Sidaway & Hand, 1993; Wulf, Shea, & Matschiner, 1998). The alternative argument is known as the guidance hypothesis (Chen, 2001; Mononen et al., 2003; Weeks & Kordus, 1998; Yao, Fischman, & Wang, 1994; Young & Schmidt, 1992), which holds that frequent feedback helps to guide and maintain a learner’s performance during acquisition, however it is detrimental to performance once feedback is withdrawn. The learner may be prevented from engaging in processes such as error detection, internal feedback, and information processing, and develop a dependency on the feedback. Thus, it would be beneficial to learning over the long term to have less frequent feedback. Others found that there was no difference when using either frequent or reduced frequency feedback schedules (Boyce, 1991).

Several different schedules for administering feedback, such as reduced frequency, bandwidth, faded, summary, and average feedback schedules, have been explored by researchers (Chen, 2001; Mononen et al., 2003; Yao, Fischman, & Wang, 1994; Young & Schmidt, 1992). The reduced feedback method simply reduces the frequency of feedback. Some commonly used frequencies are 50%, 33%, and 20%. This means that feedback is given every second, third, or fifth trial, respectively, and the feedback given pertains to the previous attempt. In the bandwidth feedback method there is a prearranged level of tolerance. If the movement falls in this acceptable level, no feedback is given, but if the movement is outside of this acceptable range, feedback will be given. The faded feedback method starts with a relatively high feedback frequency while the learner is in the acquisition stage and, as the learner progresses the feedback frequency is gradually decreased. In the summary feedback method, feedback is withheld for several trials, and is then presented as augmented information about every trial, often in the form of a graph. The average feedback method is a variation on summary feedback in which feedback is withheld for several trials and feedback about the mean of those trials is given, usually verbally.

The majority of the research available pertains to knowledge of results (Boyce, 1991; Sidaway & Hand, 1993; Weeks & Kordus, 1998; Young & Schmidt, 1992). It is uncertain whether these principles can be applied to other types of feedback, such as knowledge of performance. Weeks and Kordus (1998) found that a group receiving 33% KP feedback performed better at a soccer throw-in skill than a group that received 100% KP feedback even in acquisition. Mononen et al. (2003) found that a group receiving 100% KP feedback performed better than a group receiving 50% KP in the acquisition of a shooting task, however this increased performance disappeared in the 10 day retention period. Boyce (1991) found no difference in the performance of a shooting task between groups that received 100% KP feedback and 20% summary KP feedback. With the paucity of research in the area of KP, it is difficult to determine what type of KP schedule is optimal for learning.

1.3 STATEMENT OF THE PROBLEM AND HYPOTHESIS

1.3.1 The Problem

Does the knowledge of the optimal movement pattern predicted by the computer optimization facilitate learning by increasing performance of the free throw in wheelchair basketball?

1.3.2 Research Hypothesis

1. Knowledge of an optimal movement pattern for the free throw in wheelchair basketball will result in greater number of successful free throws scored than if the subjects receive no instructional feedback (no-feedback group), or if they receive only video feedback (video-only group).

1.3.3 Assumptions

It was assumed that:

1. All participants had no previous experience with wheelchair free throw shooting.
2. All participants had adequate upper body strength and trunk stability to successfully throw a basketball from a wheelchair placed at the free throw line to the backboard.
3. All participants refrained from playing wheelchair basketball for the duration of the study.
4. All participants were not currently playing standing basketball competitively.

1.3.4 Limitations

Differing levels of experience with standing basketball free throw shooting may have an effect on the performance of wheelchair free throw shooting for the participants.

1.3.5 Delimitations

The results of this study can only be generalized to able-bodied males with adequate upper body strength and trunk stability.

Chapter 2 – Methodology

2.1 RESEARCH DESIGN

Prior to the research study, a pilot study was conducted that compared the free throw movement patterns of expert wheelchair basketball players to the predicted optimal free throw movement pattern. For this pilot study, 4 able-bodied males from the Saskatchewan Men's Wheelchair Basketball Team participated on one occasion (see section 2.3.2).

The design chosen for the research study was a randomized groups, controlled true experimental repeated measures design (Creswell, 2003). Using nQuery Advisor® Release 3.1 software, it was determined a priori that when the sample size in each of the 3 groups is 11, a one-way analysis of variance will have 80% power to detect, at the 0.050 level of confidence, a difference in means characterized by an improvement of 1 successful free throw in the optimal pattern group compared to the controls. This calculation utilized values reported by Onestak (1997) for the mean shooting performance (32.2%) and standard deviation (6.5) of his control group.

In the study, 33 male participants were randomly assigned to three groups (optimal pattern, video-only, and no-feedback) (see section 2.4.3) by rolling a die (Table 2.1). Each participant had an equal opportunity to be randomized to each of the three groups to ensure random assignment.

Table 2.1. Criterion for assigning to groups

Die Roll	Group
1 or 6	Optimal Pattern
2 or 5	Video-only
3 or 4	No-feedback

This study was approved by the University of Saskatchewan Biomedical Research Ethics Board (Appendix A). Prior to initiation of the program, the participants were provided with a letter of information (Appendix B) explaining the purpose of the study, procedures, potential risks and benefits, and the voluntary nature of participation. Contact numbers of the researchers were provided and the rights of the participants, including the right to withdraw from the study, were explained therein. A check for exclusion criteria was done to ensure the suitability of the participants and then a consent form (Appendix B) was completed by the participants.

The study was conducted over a three week period for each participant (Figure 2.1). Initially, all the participants performed a pretest. One week after the pretest, the participants partook in training on three days over one week. There was a rest day after each training session. At the conclusion of training on the first two days, the participants completed an acquisition test. On the third training day, a post-test was conducted. One week following the post-test, a retention test was conducted (see section 2.4).

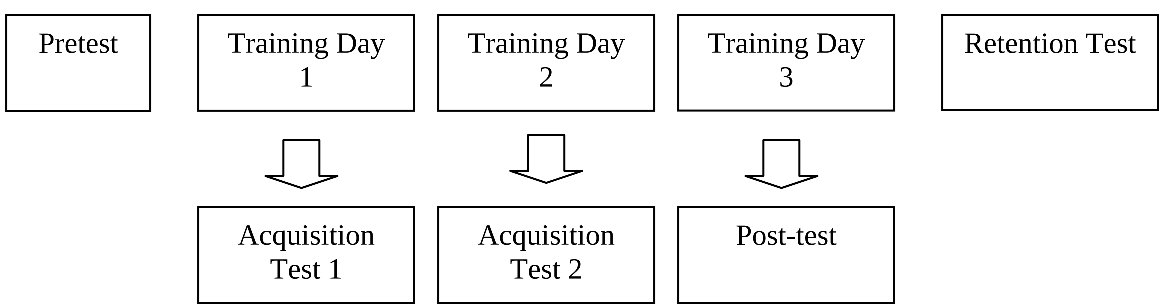


Figure 2.1. Flowchart of study design

2.2 PILOT STUDY

This pilot study was conducted to increase the external validity of the study. Realistically, it is not possible to recruit 33 people who use wheelchairs and have no conditions affecting the upper body in the Saskatoon area. Thus, a decision was made to recruit non-disabled participants to take part in the study so that there would be enough participants for adequate statistical power. However, the downside of this decision is that the results of such a study may not apply to the population of interest, which is people who use wheelchairs. Thus, the members of the Saskatchewan Wheelchair Basketball Team were invited to participate in the pilot study. Four players from the Saskatchewan Wheelchair Basketball Men’s Team, who have been classified as 3-4.5 according to the IWBF classification system, came to the College of Kinesiology Physical Activity Complex gymnasium on one occasion. Prior to initiation of the program, the participants were provided with a letter of information (Appendix C) explaining the purpose of the study, procedures, potential risks and benefits, and the voluntary nature of participation. Contact numbers of the researchers were provided and the rights of the participants, including the right to withdraw from the study, were explained therein. A check for exclusion criteria was done to ensure the suitability of the participants and then a consent form (Appendix C) was completed by the participants.

Several measurements were taken from these participants. Their body mass, shoulder height from the floor and arm segment lengths were measured and entered into the optimization computer program (see section 2.4.2.1). The 4 members of the team that participated all happened to be able-bodied, and so their body weight could be determined using the same weigh scale as the other participants in the study. Next, they performed a warm-up of 10 free throws. They were then videotaped while shooting 10 free throws and the number of successful free throws was recorded. Their body measurements were used to generate their own personal optimal free throw movement patterns, and videos of their successful free throws were compared to their optimal patterns. This group did not partake in any training for the purposes of this study.

2.3 PARTICIPANTS

This study looked exclusively at males, as there is reason to expect performance differences between the sexes. Differences in size, strength, and previous experiences between the sexes may confound the study. From preliminary tests using female participants, there was reason to expect a floor effect. Several of the females tested could not throw the ball far enough to make a successful basket, whereas none of the male participants examined had this problem. Therefore, it was decided that male participants would be examined. For the first part of the study, 33 male volunteers between the ages of 20 and 30 were recruited from the University of Saskatchewan and City of Saskatoon, via posters (Appendix D) and word of mouth. These participants were then randomly divided into three groups of eleven participants.

2.3.1 Inclusion Criteria

1. males over 18 years of age.
2. no use of a wheelchair

2.3.2 Exclusion Criteria

1. presence of any conditions affecting upper body strength and/or flexibility.
2. inability to propel a basketball from a wheelchair positioned at the free throw line to the backboard of the basketball hoop.
3. current participation in competitive basketball or wheelchair basketball.
4. previous participation in wheelchair basketball
5. presence of pain or injury in the dominant arm or shoulder.

2.4 PROCEDURES

2.4.1 Pretest

One week prior to the training, all participants completed a pretest. Prior to the pretest, the participants were seated in the wheelchair so that their body positions were standardized. The participants were instructed to sit to the back of the chair, with their feet on the footrests and backs against the back of the chair. Once seated in the wheelchair, the participants were positioned at the free throw line and were asked to shoot the basketball at the backboard. If the participants were able to shoot the basketball far enough to contact the backboard, it was decided that they had adequate strength to shoot a wheelchair free throw. They then warmed up with 10 wheelchair free throws. In the pretest, each participant threw 10 free throws from a wheelchair while being videotaped. The number of successful free throws was recorded for each participant. Successful free throws were defined as those free throws that go through the basketball hoop without touching the backboard. This restriction will help to eliminate the effects of the backboard on shot performance (Kladopoulos & McComas, 2001). A shot that contacted the rim and went through the basket was considered to be a successful free throw.

At this time, several measurements were taken from the participants in the optimal pattern group. Their body mass, shoulder height from the floor and arm segment lengths were measured and entered into the optimization computer program.

2.4.2 Testing Procedures

All of the participants underwent similar testing procedures, except for the type of feedback that they received. Several measurements were also taken from the participants in the optimal pattern groups on the day of the pretest, as described below.

2.4.2.1 Measurements

In order to personalize the optimization, measurements of the body segments (Appendix E) involved in the free throw were taken from the participants in the optimal pattern group. The segments that were measured were the upper arm, forearm, and hand of the dominant arm. These segments were measured in a systematic way to ensure an accurate measure of the segments, as follows.

The upper arm segment length was measured as the distance between the tip of the acromion process of the shoulder, and the tip of the olecranon process of the elbow. The lower arm segment length was measured as the distance between the tip of the olecranon process of the elbow to the ulnar styloid of the wrist. The hand segment length was measured as the distance between the ulnar styloid of the wrist to the second knuckle of the middle finger. These segments were measured in centimeters to the nearest 0.1 cm.

Another measurement that was necessary for the computer simulation was the height of the shoulder from the floor. For this measurement, the participants were seated in a Quickie™ sport wheelchair with a seat height of 45 cm. The shoulder height was measured as the distance between the floor and the acromion process of the shoulder.

The final measurement that was taken from the participants was body mass. The participants stood on a weighing scale in shorts and a t-shirt without footwear. Body mass was recorded in kilograms to the nearest 0.1 kg. Their total body mass value was then used to estimate the inertial parameters of their arms in the computer optimization (De Leva, 1996).

2.4.2.2 Testing

On each testing occasion, the participants were seated in a Quickie™ sport wheelchair with a seat height of 45 cm. From the advice of the expert wheelchair basketball players, the wheelchair was positioned at an angle of approximately 30^o from the free throw line, with the dominant arm closest to the basket. The wheelchair should not be positioned straight on to the basket, as it will roll back when a shot is taken in the same plane as the chair. The angle of 30^o was suggested arbitrarily and when the players were positioned the angle was approximated. The point where the large wheels begin to contact the floor was positioned directly behind the free throw line. Over the course of each training session, the positioning of the participants was repeatedly corrected as their body movements and fidgeting changed the position of the chair in regard to the free throw line. The participants completed a warm-up of 10 wheelchair free throws. After the warm-up, all participants were videotaped while shooting their training free throws. The video camera was mounted on a tripod and placed perpendicular to the plane of motion, at a distance of seven meters away, to the side of the participant's dominant throwing arm. A frame rate of 30 frames per second was used. A shutter factor of 60 was used. This was the maximum shutter factor that could be used with the amount of light in the gymnasium. They then proceeded to throw 3 sets of 15 free throws, for a total of 45 free throws, with a two minute rest between each set so that their arms did not get fatigued during practice (Figure 2.2). A reduced frequency feedback schedule was used in accordance with the guidance hypothesis. This hypothesis states that less frequent feedback should increase the performance and retention of the skill. While shooting the free throws, each group received their type of feedback after every fifth free throw, as outlined below. As it is uncertain which feedback schedule is most effective, this method was chosen for its practicality. A faded feedback schedule would be difficult to implement with only 3 training sessions. An average feedback schedule would be difficult to represent with the video feedback. More frequent feedback would lead to an increase in transition time where the participants wait for feedback while the video is uploaded from the camera to the computer and the optimal pattern is being superimposed. Thus, a reduced frequency feedback schedule giving feedback after every fifth throw was deemed the most practical method in this instance.

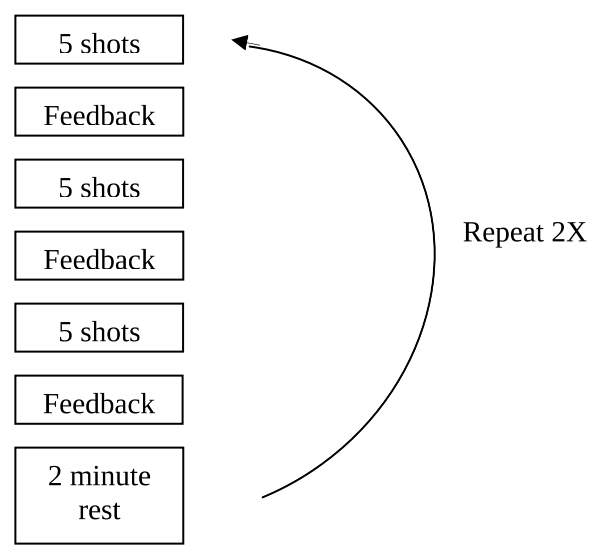


Figure 2.2. Flowchart of procedures used at each training session

2.4.3 Training Programs

2.4.3.1 No-feedback Group

The no-feedback group performed 3 sets of 15 free throws on 3 days in a week. Participants in this no-feedback group were videotaped, but they did not receive any augmented feedback on their free throws. They simply had a 30 second rest after every fifth free throw.

2.4.3.2 Video-only group

Feedback can be seen as having dual roles, motivation and information (Hebert & Landin, 1994). Viewing video of their previous free throw attempt provides the participants with both motivation and information, without any information on their optimal pattern. The video-only group was included in the study to ensure that any improvement in the optimal pattern group could not be attributed to the participants seeing video of their free throw attempts. The video-only group also performed 3 sets of 15 free throws each day over the three training sessions. Participants in this group were also videotaped while shooting their free throws. During training, after every fifth free throw, the participants viewed video of their first free throw attempt of the five.

2.4.3.3 Optimal Pattern Group

The optimal pattern group performed the same number of free throws as the two previous groups however, they were provided with visual and verbal feedback regarding their optimal free throw movement pattern. Any improvement over the video-only group can thus be attributed to the knowledge of their optimal movement pattern and the verbal feedback that was given. Prior to the training, a personal computer optimization for the free throw in wheelchair basketball was made for each participant in the group. The computer program Poser™ was used to develop a life-like adult male figure to act as the model to display the optimal movement pattern. During training, after every fifth free throw, the participants viewed their personalized optimal movement pattern superimposed over video of their first free throw attempt of the five. The researcher used verbal cues to guide the participants to focus on the factor which needed the most improvement in their free throw movement patterns. This verbal feedback often related to the release angle used, the speed of the movement, or the movement of one of the arm segments.

2.4.4 Acquisition Tests

At the conclusion of training of the first two sessions, after a five minute rest, all participants conducted an acquisition test. Each participant threw 10 free throws, without any feedback. Each participant was videotaped, and the number of successful free throws was recorded.

2.4.5 Post-test

Five minutes after training on the third day, all participants conducted a post-test. Each participant threw 10 free throws, without any feedback. Each participant was videotaped, and the number of successful free throws was recorded.

2.4.6 Retention Test

One week after the training was completed all participants conducted a retention test. The purpose of this test was to see if semi-permanent learning has occurred. Prior to the retention test, the participants completed a warm up of 10 free throws. For the retention test each participant threw 10 free throws without any feedback. Again, they were videotaped, and the number of successful free throws was recorded.

2.4.7 Statistical Analysis

SPSS™ 13.0 for Windows was used for all statistical analyses. Descriptive statistics were calculated for the data. A 3 x 5 (group x time) factorial ANOVA with repeated measures on the time factor was used to assess the effects of optimal pattern training, video training, and no specific training on free throw success in wheelchair basketball over each testing occasion. The level of significance was established at $p \leq 0.05$ for the analysis.

2.4.8 Video Analysis

The video analysis program, HU-M-AN™ was used for the video analysis. The videos of the expert participants from the pilot study were analyzed to calculate approximate release angles and velocities to be compared to the corresponding values from their personal optimizations. The diameter of the basketball was used as a scaling factor. The video of the 4 expert participants from the pilot study was analyzed to calculate approximate release angles and velocities. The pretest and post-test videos of 4 participants from each group were randomly selected for the video analysis. It was decided to analyze the videos of 4 participants from each group so that there would be the same number of video analyses to be compared to the expert participants. The pretest videos were analyzed to calculate approximate release angles and velocities, and were compared to find any observable differences between groups. The posttest videos of the same participants were also analyzed and compared to find any observable differences between groups. The posttest videos were also compared to each individual's optimal release conditions. Lastly, the pretest and posttest videos of these selected participants were compared to each other to see how each individual's free throw pattern changed over the training period.

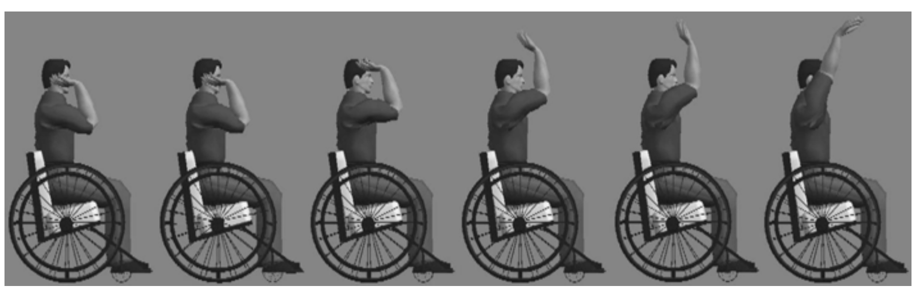
Initially, the video of the first two participants were analyzed by digitizing points on the shoulder, elbow, wrist, and ball on 20 frames of the video and using a butterworth filter to smooth the data. From this, a graph of the ball velocities was developed and the point at which release occurred was located to find the release velocity. The same was done for release angle for the shoulder. However, it was found that a simpler method of digitizing the centre point of the ball before release and the same point after release resulted in a very similar calculation of release velocity. Also, stopping the video at the point were the arm was extended after release and digitizing the shoulder joint and the elbow joint resulted in a similar calculation of release angle. As the second method gave comparable results and was much less time consuming, the simpler method of digitizing two points was used for the remainder of the participants.

Chapter 3 – Results and Discussion

3.1 RESULTS

For the pilot study, the analysis of the videos of the 4 expert participants revealed that the release conditions used by this group were very similar to those predicted to be optimal for each individual. The release velocities and release angles of the expert participants ranged from 7.3–8.6 m/s, with an average of 7.97 m/s, and 52^{o}–58.5^{o}, with an average of 54.3^{o}. These values are very similar to the predicted optimal values of 7.42 m/s and 53.8^{o}. Also, when observing the participants' movement patterns as compared to their optimal movement patterns, they are very similar (Figure 3.1).

a



b

Figure 3.1. Comparison of the sequential movement pattern of an expert player (a) and that produced by the optimized model (b).

The results for the statistical analyses of the primary study are presented below. Descriptive statistics were calculated for the data (Table 3.1). All analyses were completed using $p \leq 0.05$ as the criterion for statistical significance. A 3 x 5 (group x time) factorial ANOVA with repeated measures on the time factor was used to assess the effects of optimal pattern training, video training, and no specific training on free throw success in wheelchair basketball over each testing occasion. There was no significant main effect of time (i.e. training session), $F(4,120)=.692$, $p=.599$ (Table 3.2). There was no significant training session * group interaction, $F(8, 120)=.819$, $p=.587$ (Table 3.2). There also was no significant main effect of training group, $F(2, 30)=.060$, $p=.942$ (Table 3.3). As there was no overall statistical significance, post hoc tests were not conducted on the data.

Table 3.1. Means and standard deviations for successful baskets in each training group at each training session.

Session	Group	Mean	Std. Deviation	N
Pretest	No-feedback	2.27	1.489	11
	Video-only	2.27	1.737	11
	Optimal pattern	2.09	2.023	11
Session 1	No-feedback	2.18	1.601	11
	Video-only	1.45	1.753	11
	Optimal pattern	1.91	2.256	11
Session 2	No-feedback	1.64	1.362	11
	Video-only	2.55	1.368	11
	Optimal pattern	2.45	2.252	11
Post-test	No-feedback	2.27	2.005	11
	Video-only	2.00	1.265	11
	Optimal pattern	2.73	2.149	11
Retention	No-feedback	2.91	1.758	11
	Video-only	2.27	1.555	11
	Optimal pattern	2.09	1.514	11

Table 3.2. ANOVA source table for Within-Subjects Effects.

Source	**SS**	**Df**	**MS**	**F**	**Sig**
Time	6.327	4	1.582	.692	.599
Time*group	14.982	8	1.873	.819	.587
Error	274.291	120	2.286		

Table 3.3. ANOVA source table for Between-Subjects Effects.

Source	**SS**	**Df**	**MS**	**F**	**Sig**
Group	.776	2	.388	.060	.942
Error	194.618	30	6.487		

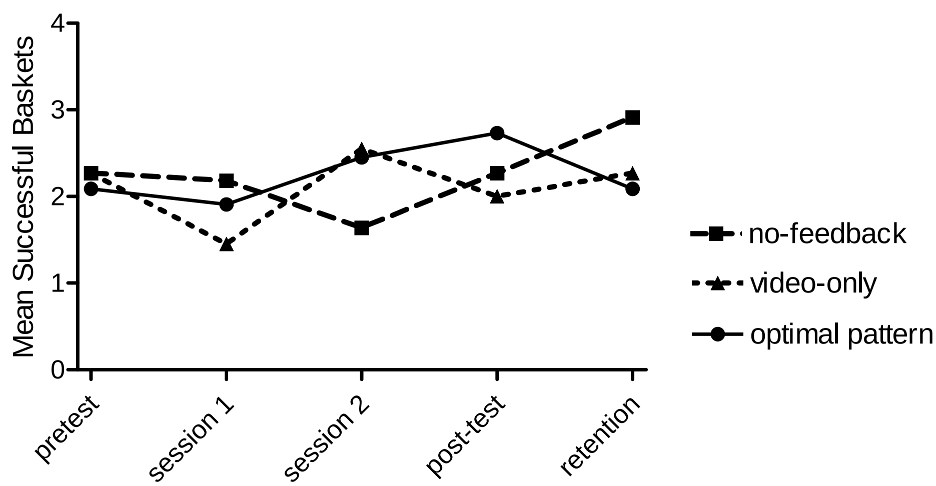


Figure 3.2. Mean successful free throws for the no-feedback, video-only and optimal pattern groups at each testing session.

The calculated optimal free throw movement pattern changed very little with each individual's body measurements. From the smallest participant to the largest participant (Table 3.4), the release angle and velocity ranged from 55.7^{o} and 7.60 m/s to 53.8^{o} and 7.45 m/s. Also, as the wheelchair basketball players (pilot study) brought their own wheelchairs, the height of their wheelchairs varied. The wheelchair that the other participants in the study used had a seat height of 45 cm, whereas the maximum seat height allowed by the rules is 53 cm and a cushion with a thickness of up to 5 cm can be used for players classified as 3.5 to 4.5. Thus, the expert participants from the pilot study could be positioned a maximum of 13 cm higher than the other participants in the study. Looking at a participant from the optimal pattern group and one from the pilot study with similar body measurements (Table 3.4) and an increase in release height of 18 cm, the optimal release angle and velocity ranged from 55.8^{o} and 7.57 m/s to 53.8^{o} and 7.42 m/s. Thus, it appears that little is gained by generating a new optimal movement pattern for each individual.

Table 3.4. Body measurements and optimal release characteristics of 4 representative participants. The first two rows compare members from the optimal pattern group, and the second two rows compare a member from the optimal pattern group to an expert from the pilot study.

Participant	Weight	Release Height	Upper arm	Lower arm	Hand	Release angle	Release velocity
Smallest in optimal pattern group	56.7 kg	99.3 cm	33.0 cm	25.0 cm	15.3 cm	55.7^{o}	7.60 m/s
Largest in optimal pattern group	114.8 kg	102.4 cm	33.5 cm	31.0 cm	14.5 cm	53.8^{o}	7.45 m/s
Like measurements, low wheelchair	79.4 kg	102.0 cm	33.5 cm	26.5 cm	15.6 cm	55.8^{o}	7.57 m/s
Like measurements, high wheelchair	76.2 kg	120.0 cm	31.2 cm	26.3 cm	16.0 cm	53.8^{o}	7.42 m/s

From analysis of the video of the 4 selected participants from each group it was found that the participants in each group used a large range of release conditions in their pretests (Table 3.5). After the training period, the selected participants began to use differing release conditions specific to their group (Table 3.5). The release velocities and release angles of the participants in the no-feedback group were very similar to their pretest ranges. The participants in the video-only group had a larger range of release velocities, and a slightly smaller range of release angles. The participants in the optimization group had a smaller range of both release velocities and angles that more closely resembles optimal release conditions.

Table 3.5. Ranges of release conditions for the participants in each group at the pretest and post-test.

Treatment	Range of pretest release conditions		Range of post-test release conditions	
	Release Angle	Release Velocity	Release Angle	Release Velocity
No-feedback Group	$40.0^{o} – 51.0^{o}$	7.1 - 8.5 m/s	42.6^{o} - 48.8^{o}	7.2 - 8.6 m/s
Video-only Group	$40.0^{o} – 57.0^{o}$	7.3 - 8.3 m/s	$42.0^{o} – 54.0^{o}$	6.6 - 8.8 m/s
Optimal Pattern Group	$32^{.0o}$ - 58.5^{o}	7.5 - 9.1 m/s	48.0^{o} - 58.4^{o}	7.5 - 8.5 m/s
Optimal Prediction			53.8^{o} - 55.8^{o}	7.4 - 7.6 m/s

From the pretest to the post-test, the wheelchair free throw movement pattern of participants in the optimal pattern group changed substantially. On average, their release angles increased by approximately 4.1^{o}, and ranged from no increase to an approximately 13.7^o increase. The participants in the no-feedback group showed an average increase in release angle of 1.4^o and ranged from a decrease of approximately 2.8^o to an approximate increase of 4.5^o. The participants in the video-only group showed an average increase of 1.2^o and ranged from a decrease of approximately 2.7^o to an approximate increase of 2.6^o. Several of the participants in the no-feedback group and video-only group actually showed a decrease in their release angles, whereas none of the participants in the optimal pattern group showed a decrease. The participants in the optimal pattern may have shown this increase in release angle as they were trying to emulate the steeper release angle demonstrated in the optimization.

From the video analysis, it was also apparent that the movement patterns for the participants differed according to the training they received. Beginning with the starting position, all participants in the optimal pattern group began to use a similar starting position to that of the optimization, whereas participants in the video-only and no-feedback groups used many variations of starting positions (Figure 3.3). Also, several participants in the no-feedback and video-only groups developed shots with various shot patterns, whereas participants in the optimal pattern group used free throw shooting patterns similar to their optimization free throw patterns (Figures 3.4 - 3.10).

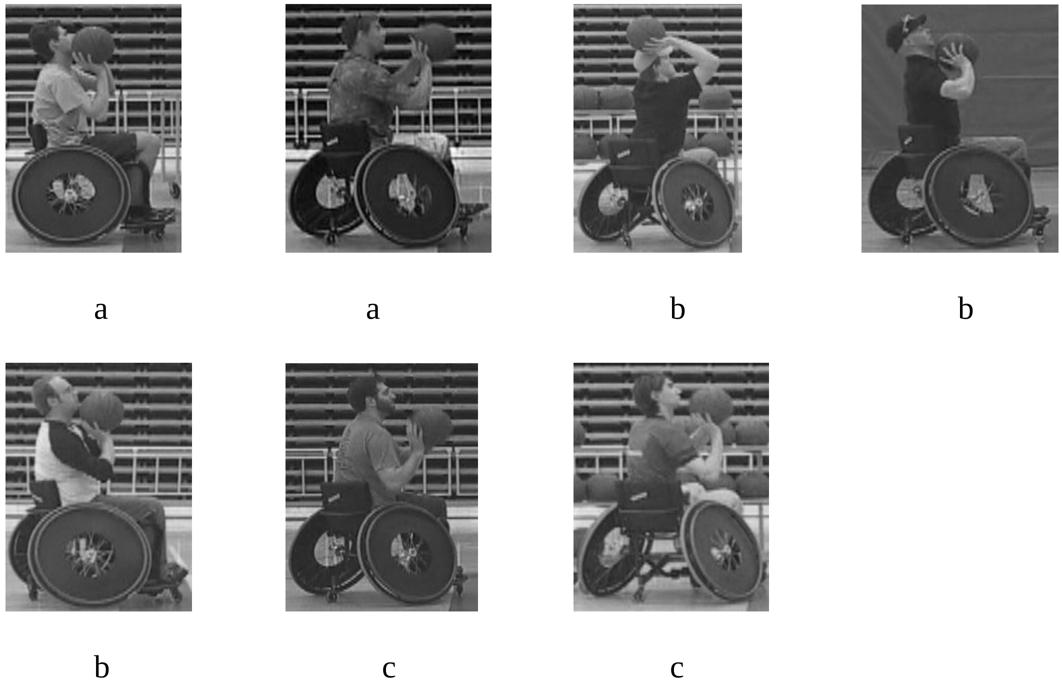


Figure 3.3 Starting positions for participants in no-feedback (a), video-only (b), and optimal pattern (c) groups in the post-test.

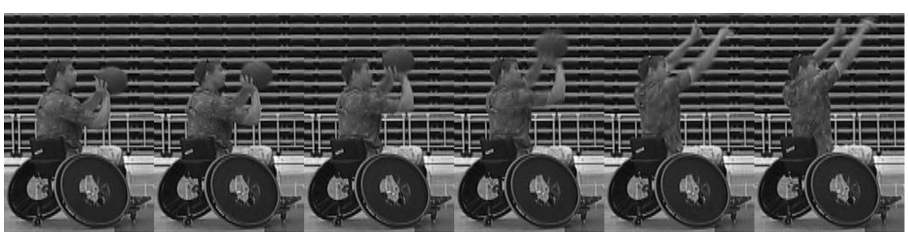
In an attempt to reach the optimal release angle, many of the participants in the optimal pattern group began to ‘kick back’, meaning that after the shot was released, they would further extend their shoulder so that they ended with a steeper release angle that more closely resembled the optimal pattern. Several of the participants in the video-only and no-feedback groups would either use an exaggerated wrist flick, or they would not use any wrist movement at all. Several of the no-feedback and video-only participants would also not fully extend their elbow joint. Many of the participants in these groups would also ‘kick back’, similarly to the optimal pattern group. Several participants began using two hands and pushing the ball out of the middle of the two hands. This allowed the participants to propel the ball far enough with ease, however, their accuracy was compromised and many of the shots missed the basket by a large margin. The participants who used this technique often used a flat shot that went long and bounced hard off the backboard. They also tended to miss laterally more often than the participants that used a one-handed shot.

A

B

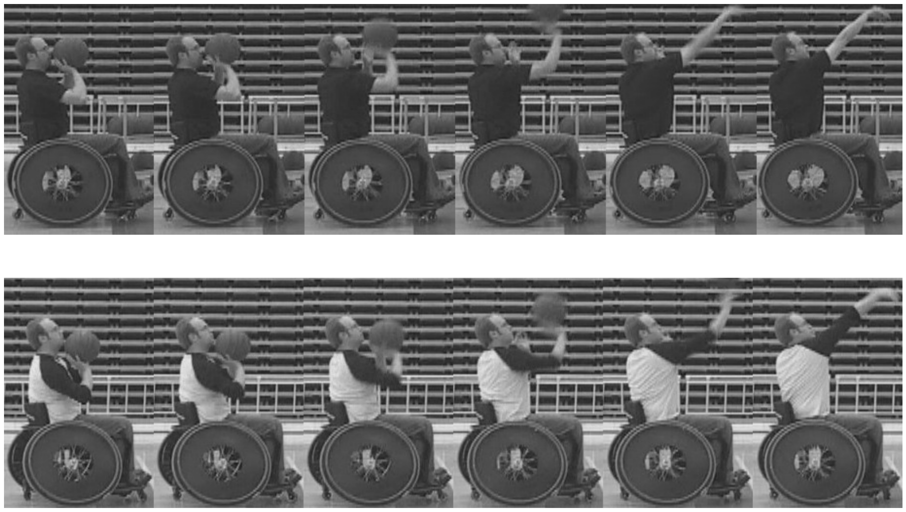
Figure 3.4. Sequential free throw movement patterns for participant in the no-feedback group during the pretest (A) and post-test (B).

A



B

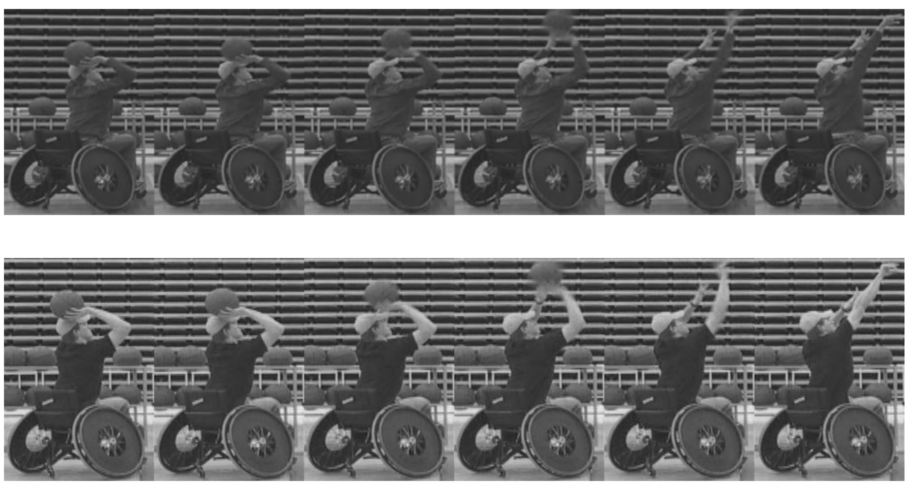
Figure 3.5. Sequential free throw movement patterns for participant in the no-feedback group during the pretest (A) and post-test (B).



A

B

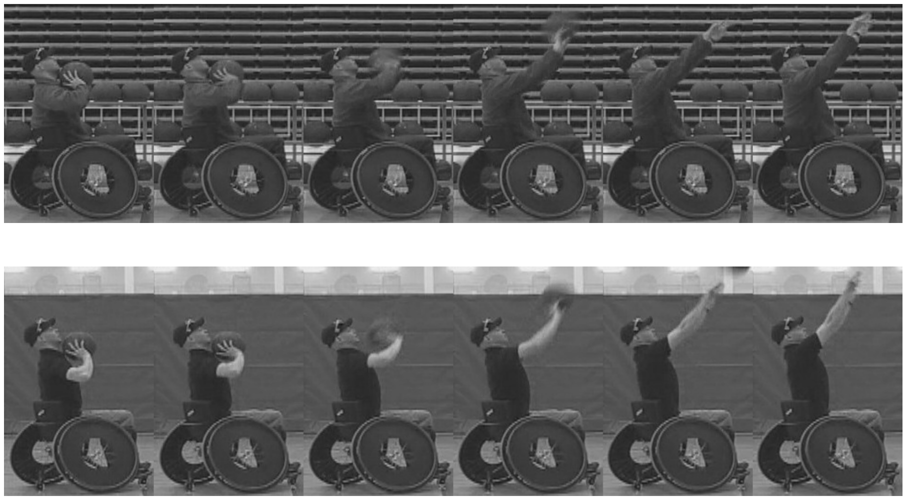
Figure 3.6. Sequential free throw movement patterns for participant in the video-only group during the pretest (A) and post-test (B).



A

B

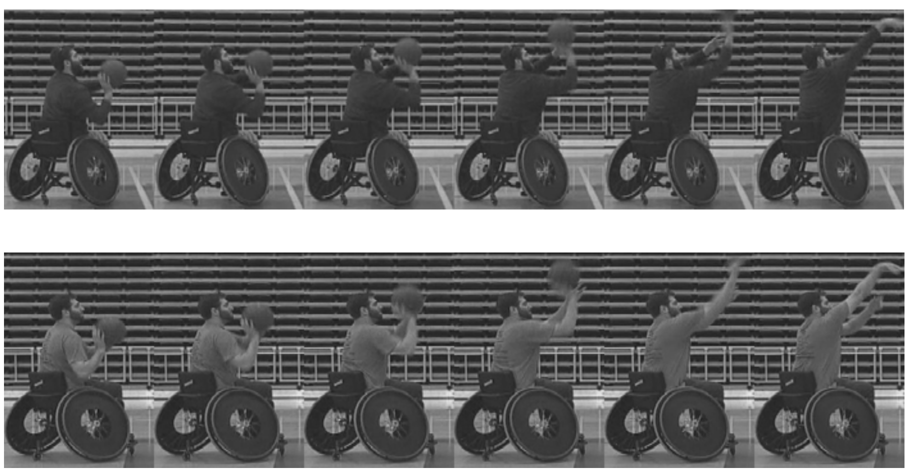
Figure 3.7. Sequential free throw movement patterns for participant in the video-only group during the pretest (A) and post-test (B).



A

B

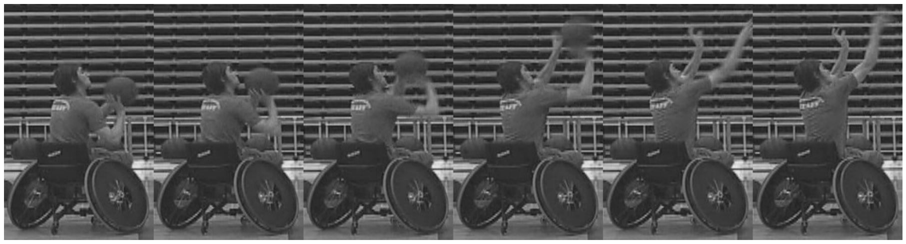
Figure 3.8. Sequential free throw movement patterns for participant in the video-only group during the pretest (A) and post-test (B).



A

B

Figure 3.9. Sequential free throw movement patterns for participant in the optimal pattern group during the pretest (A) and post-test (B).

A 

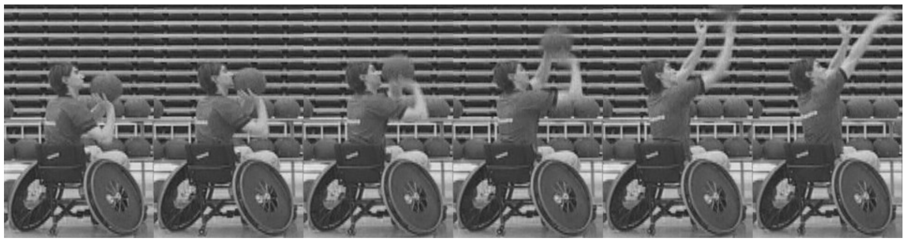
B 

Figure 3.10. Sequential free throw movement patterns for participant in the optimal pattern group during the pretest (A) and post-test (B).

One difficulty with the digitization process was blurring of the image when fast movement occurred. The shutter factor of 60 was not high enough to get a clear image of the moving arm and basketball, however there was not enough light in the gymnasium to allow the use of a larger shutter factor. Once the ball was moving quickly, it appeared as a double-image. During optimization, the ball that was farthest along in its movement path was digitized (Figure 3.11). The arm was also slightly blurred however most of the problem with the image was localized to the forearm and hand segments, which were moving faster than the upper arm. To calculate the release angle, the shoulder and elbow were digitized, and so the blurring was not a significant problem.

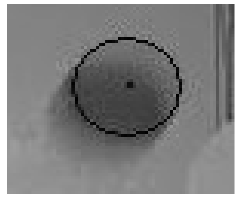


Figure 3.11. Selection of the centre point of the basketball during digitization. The circle represents the outline of the image used for digitization and the dot in the centre represents the chosen centre point of the image of the ball that was farthest along in its movement path

3.2 DISCUSSION

When comparing the free throw movement patterns of the elite wheelchair basketball players to their optimal free throw movement patterns, there was little difference. On average, the elite wheelchair basketball players were successful in 7 out of 10 of their free throw attempts. Their movement patterns used while shooting a successful free throw were very similar to their predicted optimal free throw movement patterns. This lends support to the external validity of the optimization. Apparently, with experience, these elite wheelchair basketball players developed a free throw movement pattern through training that was very close to that predicted to be optimal by the model.

The purpose of this study was to determine the effect of the knowledge of an optimal free throw movement pattern on the performance of the free throw in wheelchair basketball. For the length of training time used, the statistical analyses indicated that there was no difference between the group that had knowledge of their personalized optimal movement pattern and the control group that did not receive any feedback. A second control group was included in the study. This group was called the video-only group, and its purpose was to ensure that any improvement of the optimal pattern group during the course of the study was not due to information received from the participants seeing video of their free throws. In the research hypothesis it was theorized that knowledge of an optimal movement pattern for the free throw in wheelchair basketball would result in greater number of successful free throws scored than no-feedback and video-only groups (Hypothesis 1.3.2.1). This hypothesis was not supported by the data, as there was no significant difference in successful free throws scored between the optimal pattern group and the video-only and no-feedback groups. There was also no significant difference in successful free throws scored between the no-feedback group and the video-only group.

Although the participants in the optimal pattern group did not show a significant improvement in successful free throw attempts over the video-only and no-feedback groups, their free throw movement patterns were beginning to resemble their optimal templates. When visually comparing their pretest video to their posttest video, the wheelchair free throw movement pattern of participants in the optimal pattern group changed substantially in the desired direction. Several of the participants in the no-feedback and video-only groups actually showed an undesired decrease in their release angles, whereas none of the participants in the optimal pattern group showed a decrease.

In regards to the form of the shots, all of the participants in the optimal pattern group developed a similar movement pattern to one another. They generally began with their arm at their side, with their elbow near their hip and their hand near their shoulder, and ended with an average release angle of approximately 51.7^o. In an attempt to reach the optimal release angle (approximately 53.8^o – 55.8^o), many of the participants began to 'kick back', meaning that after the shot was released, they would further extend their shoulder so that they ended with a steeper release angle that more closely resembled the optimal pattern. The participants were generally unaware that they were doing this and, even when their attention was brought to it, they did not discontinue this practice. This kickback could be due to the force exerted on the hand by the ball at release. Newton's third law (law of reaction) states that for every action, there is an equal and opposite reaction (Hall, 2003). Thus, when the hand exerts a force on the ball, the ball exerts a force that is equal in magnitude and opposite in direction on the hand. The ball could be pushing the hand, and thus the arm, in the reverse direction, causing the 'kick back'. The 'kick back' could also be a natural reaction to the elbow extension and wrist flexion during the time when the upper arm is nearing a vertical position. According to Newton's law of reaction in angular form, for every torque exerted by one body on another, there is an equal and opposite torque exerted by the second body on the first (Hall, 2003). When the elbow extensors and wrist flexors move the forearm and hand in the forward direction, an equal and opposite torque will be exerted to move the upper arm in the reverse direction, thus the observed 'kick back' occurs.

The participants in the video-only and no-feedback groups had extensive variations in movement patterns. Several participants would begin their free throws with their upper arm near parallel to the floor, with a shoulder angle of approximately 90^{o}. Due to this, they were applying force to the ball for a shorter period of time, and they were often unable to reach the basket with the ball. Several of the participants in the video-only and no-feedback groups would either use an exaggerated wrist flick, or they would not use any wrist movement at all. Several of the no-feedback and video-only participants would also not fully extend their elbow joint. Many of the participants in these groups would also 'kick back', similarly to the optimal pattern group. As the participants in these groups were not given any instruction and were able to explore different ways of shooting a free throw, several participants began using two hands and pushing the ball out of the middle of the two hands. This technique allowed the participants to propel the ball far enough with ease, however, their accuracy was compromised and many of the shots missed the basket by a large margin. The participants who used this technique often used a flat shot that went long and bounced hard off the backboard. They also tended to miss laterally more than the participants that used a one-handed shot.

Three training sessions using knowledge of the optimal free throw pattern did not help participants improve their wheelchair free throw shooting to a greater extent than the use of no-feedback or video-only feedback during training. There are several reasons why an improvement may not have been seen.

One possible reason that the results did not show a significant difference in successful free throws between the optimal pattern group and the video-only and no-feedback groups could be the measure used. The number of successful free throws scored out of 10 shot attempts was the instrument used to measure free throw success in this study. This instrument may not have been sensitive enough to detect a difference between the groups in successful free throws scored. The instrument also had low test-retest reliability. Participants often demonstrated a difference of 4 to 6 successful free throws from one testing occasion to the next. A more sensitive and reliable measure may have been able to detect an improvement in free throw success in the treatment group.

For the participants in this study, three training sessions may not have been adequate for the acquisition of this arm movement pattern. According to Kernodle and Carlton (1992), videotape feedback should be given over a minimum period of 5 weeks for motor skill learning to take place. However, they did not specify how often video feedback should be given over these 5 weeks. Thus, in this present study more training sessions may have been necessary for improvements in free throw shooting success to become evident.

The feedback schedule that was used in the study may not have been optimal for the learning of a novel skill, such as the free throw in wheelchair basketball. Most Canadian males have attempted shooting free throws at one time or another, however, the movement pattern necessary for the free throw from a wheelchair is very different from that for the standing free throw. This makes the wheelchair free throw a novel task for all of the participants, as any experience with wheelchair basketball was a restriction for the study. Giving feedback after every fifth free throw attempt may not have been adequate for the learning of a novel task. More frequent feedback may have increased learning of the skill.

For the purpose of this study, more frequent feedback may have become more of a hindrance. The feedback for the optimal pattern group consisted of a participant's optimal free throw template superimposed over video of his previous free throw attempt. The time required to upload the video from the camera onto the computer, and then superimpose the optimal pattern was substantial. It took the researcher approximately 1 minute to prepare the video feedback. However, the researcher superimposed video of the first shot of the five with the optimal pattern, and so the preparation was done while the participants were shooting the other four shots. This method prevented the participants from waiting long for the video feedback. If the optimal pattern feedback were to be shown after every shot, the participants would have spent ample time during each training session waiting for the feedback to be given. This may have been detrimental to learning. Portier and van Galen (1992) found that learning of a handwriting task was decreased when feedback was delayed rather than immediate. Morikiyo & Matsushima (1990) found that performance of a handwriting task decreased with an increased feedback delay. It is hypothesized that a delay in receiving feedback would lead to a decaying of the movement representation and a decreased association between internal feedback and the feedback given (Schmidt, 1975). However, many studies also show an increase in learning and performance with delayed feedback (Anderson, Magill, & Sekiya, 1994; Liu, & Wrisberg, 1997; Swinnen, Schmidt, Nicholson, & Shapiro, 1990). Possibly more importantly, a delay of 1 minute after each shot would at least double the amount of time the participants spent with the researcher. While shooting free throws for over an hour, the participants could have become less focused and thus less motivated towards the task at hand (Green-Demers, 1998; Ntoumanis, 2001).

Chen (2001) recommends using a faded feedback schedule to enhance learning. In this type of feedback schedule, feedback is given frequently when the learner is in the early stages of learning. Once the basics of the skill have been acquired, the feedback frequency can be reduced. Since the wheelchair free throw was a novel skill for all of the participants, they may have benefited from more frequent feedback in the early stages of learning. However, as there were only three training sessions, a faded feedback schedule would not have been appropriate.

In this study, feedback was given as knowledge of performance (KP). Most of the research on how to administer feedback has been done using knowledge of results (KR), which may not be sufficient to provide an understanding of feedback used in real world settings (Kernodle & Carlton, 1992; Schmidt & Young, 1991). One of the reasons that Schmidt and Young (1991) give for the inadequacy of KR research is that the tasks used to examine KR generally have only one degree of freedom. This means that the KR given applies only to the positioning and timing of a single dimension response (Kernodle & Carlton, 1992). The free throw in wheelchair basketball requires the control of multiple degrees of freedom. Thus, the principles that were used to guide how the KP feedback was administered may not apply to this situation.

Another limitation of using principles from KR research is that many of these studies have a goal which is isomorphic (Brisson & Alain, 1996). This means that the goal of these studies was to produce a specific movement pattern, whereas the goal of this thesis study was to get the ball through the hoop. There are many different movement patterns that could potentially result in a successful basket. When an optimal movement pattern is identified, participants may treat the reproduction of this pattern as the goal, which could be detrimental to progress towards the actual goal (Brisson & Alain, 1996). Also, even though the participants in the no-feedback and video-only groups are unaware of the optimal movement pattern, they may discover another movement pattern that leads to successful results using KR, as there are many different ways in which a basket can be scored. Brisson and Alain (1997) state that for tasks in which the goal is not isomorphic KR may be more useful than a specific template pattern. This is because KR informs the learner whether or not the goal has been achieved. In this study, all of the participants received KR, and so the extra information from the optimal pattern template may not be useful to learning.

In this study, the participants' experience in standing basketball was not accounted for. Prior to the study, it was determined that the participants had never played wheelchair basketball and were not currently playing standing basketball competitively. Several participants had played competitively in the past at the high school level and the majority had played recreationally. However, the level of experience for each participant was not recorded or controlled for in the study. Differing levels of experience with standing basketball free throw shooting could have an affect on the results of the study. Participants with more standing free throw experience could experience either positive or negative transfer to the wheelchair free throw (Schmidt & Wrisberg, 2004). If positive transfer occurred, the more experienced participants would perform better at the wheelchair basketball free throw than the participants without standing basketball experience. If negative transfer occurred, the more experienced participants would perform worse at the wheelchair basketball free throw than the participants without standing basketball experience. However, as the participants were randomly assigned to groups, the level of experience should be approximately uniform between the groups.

Another possible reason that a significant difference in successful free throws was not found could be a small sample size. At the beginning of the study, it was determined that a sample size of 11 participants per group would have 80% power to detect, at the 0.050 level of confidence, a difference in means characterized by an improvement of 1 successful free throw in the optimal pattern group compared to the controls. However, as researchers do not know what the actual effect size will be before conducting the study, a priori power analyses must be conducted using a hypothesized effect size, determined using a practical or expected mean difference and standard deviation from previous research (Onwuegbuzie & Leech, 2004). This power calculation in the present study utilized values reported by Onestak (1997) for the mean shooting performance (32.2%) and standard deviation (6.5) of his control group. If the observed effect size is actually smaller than the estimate used, the predicted sample size, as determined by running the a priori power analysis, may be underestimated. In the present study, the non-significant findings could have resulted from having too small a sample size, which leads to low statistical power.

There is also the possibility that there may have been a problem with the computer optimization itself. There may have been some factor that was not accounted for when the computer simulation was made. Upon observation of the wheelchair free throw shooting of the participants in the optimal pattern group, the majority of missed free throws fell short of the basket. The model may have overestimated the amount of force that can be generated by the upper body muscles in able-bodied males. When participants attempted to shoot free throws using the optimal movement pattern, it resulted in a slightly high arching shot. Many of the participants in the video-only and no-feedback groups would shoot shallower shots that would hit the front rim, yet bounce into the basket. For this study it was decided that a shot that contacted the rim and went through the basket would be considered as a successful free throw. Hitting the rim would increase the variability in the free throw and decrease the accuracy of the shot however a shallower shot with a lower arc may be easier for people to replicate.

From talking to the participants in the optimal pattern group, it became evident that it was difficult for them to perform the movement pattern they were being asked to replicate. The movement pattern requires that the vertical force for the free throw comes mainly from the shoulder flexion movement, and the horizontal force comes mainly from the elbow extension and wrist flexion movements. These motions are achieved using relatively small muscle groups, especially those responsible for the elbow extension and wrist flexion. It is very difficult to generate the necessary horizontal forces with these small muscle groups. In order for this to be accomplished, the elbow and wrist movements had to be very quick, snapping motions. This led to considerable muscle soreness in the forearms for several days following the training session. Although the training sessions were every second day, some of this muscle soreness may have persisted and been detrimental to performance in subsequent training sessions. Also, the movement pattern requires considerable shoulder range of motion. The participants often felt that the optimal movement pattern required greater shoulder flexion than they could accomplish. Strength and flexibility training may help to expedite improvements in the free throw shooting pattern. An increase in strength of the shoulder flexors may help individuals to generate enough force for the vertical component of the free throw. An increase in strength of the elbow extensors and the wrist flexors may help individuals to generate enough force for the horizontal component of the free throw. An increase in flexibility for shoulder flexion may allow individuals to more easily emulate the steep release angle of the optimal free throw pattern.

Chapter 4 – Conclusions

4.1 SUMMARY

The free throw is a very important skill in wheelchair basketball, and increasing players' proficiency in the skill of free throw shooting may help lead their teams to victory. As the free throw is a closed, discrete skill, it can easily be practiced and improved upon. Previously, a computer optimization program which determines a theoretically optimal movement pattern for the free throw in wheelchair basketball was developed. The purpose of this study was to evaluate the external validity of the optimization program by examining whether the knowledge of the optimal movement pattern facilitates performance of the free throw in wheelchair basketball.

The results of this study show that three sessions of training over a period of 1 week using knowledge of an optimal free throw pattern did not significantly increase success of wheelchair free throws. There was no significant difference in successful free throws scored between the optimal pattern group and the video-only and no-feedback groups. Although the participants in the optimal pattern group did not show a significant improvement in successful free throw attempts over the video-only and no-feedback groups, their free throw movement patterns were beginning to resemble their optimal template. When visually comparing their pretest video to their posttest video, the wheelchair free throw movement pattern of participants in the optimal pattern group changed substantially. This suggests that the participants in the optimal pattern group had made progress towards their optimal movement patterns, but had not yet mastered the necessary coordination to make it successful.

From studying the free throws of the members of the Saskatchewan Men's Wheelchair Basketball team, it was apparent that their techniques were very similar to their predicted optimal movement patterns. This suggests that over time, these elite wheelchair basketball players came across their optimal free throw movement pattern through trial and error. This also lends support to the predicted optimal movement pattern being an actual optimal movement pattern for the free throw in wheelchair basketball.

4.2 CONCLUSION

4.2.1 Within the limitations and assumptions previously stated, knowledge of an optimal movement pattern for the free throw in wheelchair basketball did not result in a greater number of successful free throws scored than the no-feedback and video-only groups (hypothesis 1.3.2.1 was not supported).

4.3 RECOMMENDATIONS FOR FUTURE RESEARCH

Future research should be conducted on using optimal pattern training to teach the free throw in wheelchair basketball. Suggestions for future research include:

4.3.1 Increasing the length of the training period. According to Kernodle and Carlton (1992), videotape feedback should be given over a minimum period of 5 weeks for motor skill learning to take place.

4.3.2 Using a more sensitive instrument for measuring free throw success. An instrument that grades the success of the free throw attempt as a continuum could be used. For example, a free throw attempt that goes through the hoop could be scored as 3 points; a shot that hits the rim, 2 points; a shot that is close to the rim, 1 point; and a shot that is far from the rim, 0 points.

4.3.3 Incorporating the trunk body segment into the free throw movement pattern. Using the trunk segment in the wheelchair free throw would allow players to use their abdominal muscles and hip flexors to aid in the horizontal propulsion of the ball.

4.3.4 Incorporating a counter movement in the optimization of the free throw movement pattern. An eccentric movement of the triceps muscle prior to elbow extension would provide time for the muscle to develop force and allow greater starting forces to be produced (Bobbert & Casius, 2005).

4.3.5 Examining the effects of prior arm strength and/or flexibility training on the performance of the free throw in wheelchair basketball using optimal pattern training. An increase in strength of the shoulder flexors, elbow extensors and wrist flexors could make it easier for wheelchair basketball players to generate and accurately reproduce the necessary forces to propel the basketball to the basketball hoop. An increase in shoulder flexion flexibility could make it easier for wheelchair basketball players to achieve an adequate release angle for the free throw with ease.

4.3.6 Examining different populations, such as women, and wheelchair basketball players of different playing classifications to develop an optimal free throw movement pattern that can be accomplished by people with differing abilities. From preliminary testing, several female participants were unable to propel the basketball far enough to shoot a successful free throw. However, many women of small stature are able to successfully shoot free throws. By examining their free throw shooting, more appropriate conditions could be established to create an optimal movement pattern for people with differing abilities.

4.3.7 Comparing several different feedback schedules to determine which is the most effective for increasing performance of the free throw in wheelchair basketball. These feedback schedules could include bandwidth, faded, summary, and average feedback schedules (see section 1.2.6).

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APPENDICES

APPENDIX A

ETHICAL APPROVAL

P.01/02

University of Saskatchewan
Biomedical Research Ethics Board (Bio-REB)

23-Dec-2004

Certificate of Approval

PRINCIPAL INVESTIGATOR	DEPARTMENT	Bio #
Eric J. Springings	Kinesiology	04-243

INSTITUTION (S) WHERE RESEARCH WILL BE CARRIED OUT

College of Kinesiology
105 Gymnasium Place
Saskatoon SK S7N 5C2

SPONSORING AGENCIES

UNFUNDED

TITLE:

Using Optimized Computer Simulation to Facilitate the Learning Process of the Free Throw in Wheelchair Basketball

ORIGINAL APPROVAL DATE	CURRENT EXPIRY DATE	APPROVAL OF
23-Dec-2004	01-Dec-2005	Protocol approved as submitted Consent Form (Able-bodied Participants) (02 Nov 04) Consent Form (Wheelchair-Users) (02 Nov 04) Basketball Research Study Advertisement

CERTIFICATION

The University of Saskatchewan Biomedical Research Ethics Board has reviewed the above-named research project at a full-board meeting (any research classified as minimal risk is reviewed through the expedited review process). The proposal was found to be acceptable on ethical grounds. The principal investigator has the responsibility for any other administrative or regulatory approvals that may pertain to this research project, and for ensuring that the authorized research is carried out according to governing law. This Approval is valid for the above time period. Any amendments or modifications to the approved protocol must be submitted for REB approval review and approval prior to implementation.

ONGOING REVIEW REQUIREMENTS/REB ATTESTATION

In order to receive annual renewal, a status report must be submitted to the Chair for Board consideration within one month of the current expiry date each year the study remains open, and upon study completion. Please refer to the following website for further instructions: http://www.usask.ca/research/ethics.shtml. In respect to clinical trials, the University of Saskatchewan Research Ethics Board complies with the membership requirements for Research Ethics Boards defined in Division 5 of the Food and Drug Regulations and carries out its functions in a manner consistent with Good Clinical Practices. This approval and the views of this REB have been documented in writing.

APPROVED.

Barry D. McLennan

Barry D. McLennan, Ph.D., Chair
University of Saskatchewan
Biomedical Research Ethics Board (Bio-REB)

Please send all correspondence to:

Research Services, University of Saskatchewan
Room 305, Kirk Hall
117 Science Place
Saskatoon, SK S7N 5C8
Phone: (306) 966-4053 Fax: (306) 966-2069

APPENDIX B

COVER LETTER AND CONSENT FORM

Consent Form

Title: Using optimized computer simulation to facilitate in the learning of the free throw in wheelchair basketball

Investigators:
Brianne Hamilton, B.Sc.(Kin). Graduate Student, College of Kinesiology, Physical Activity Complex, University of Saskatchewan (373-1229)
Dr. Eric Sprigings, Ph.D., Professor (Supervisor), College of Kinesiology, Physical Activity Complex, University of Saskatchewan (966-1077)

Introduction: You are being invited to participate in this research study examining the learning of the free throw in wheelchair basketball. The study will include shooting free throws from a wheelchair while being videotaped.

Voluntary Participation: Your participation is entirely voluntary, so it is up to you whether or not to take part in this study. Before you decide, it is important for you to understand what the research involves. This consent form will tell you about the study, why the research is being done, what will happen during the study and the possible benefits, risks, and discomforts

If you wish to participate, you will be asked to sign this form. If you decide to take part in this study, you are still free to withdraw at any time, without giving any reasons for your decision, and without any penalty of any sort.

If you do not wish to participate, you do not have to provide any reason for your decision not to participate.

Purpose and Objectives of the Study: The purpose of the study is to examine whether the knowledge of an optimal movement pattern will help improve free throw shooting skills in wheelchair basketball. We hypothesize that people who are shown an optimal movement pattern for the free throw in wheelchair basketball will improve their free throw shooting to a greater extent than those who are not shown the optimal movement pattern.

Procedures:
Inclusion and Exclusion criteria: In order to be included in the study, you must be able to throw the basketball the distance from the free throw line to the backboard of the basketball hoop while seated in a wheelchair. You will be excluded if you have any conditions affecting upper body strength or flexibility, any dominant arm or shoulder injury or pain, are currently participating in basketball or wheelchair basketball at any level, or have more than 2 years of previous participation in basketball or wheelchair basketball.

If you agree to participate in this study, the following will happen:

You will be assigned at random, that is, by a method of chance, to one of the three groups. You will have a 1 in 3 chance of being in a particular group:

1) Control group - This group will shoot free throws while seated in a wheelchair, without getting any feedback.
2) Video group – This group will shoot free throws while seated in a wheelchair, and will be periodically shown video of their previous free throws**.**
3) Video + Optimization group – This group will shoot free throws while seated in a wheelchair, and will be periodically shown video of their previous free throws with a personalized optimal movement superimposed over the video.

- ❖ There will also be a Wheelchair User Video+Optimization group that will be made up of people who use wheelchairs and will complete the same training as the Video + Optimization group.

The study will take place over a three week period. Initially, you will complete a preliminary (i.e. "baseline") test, which will take approximately 30 minutes. For this initial test you will arrive at the Physical Activity Complex gymnasium and will be videotaped shooting 10 free throws from a wheelchair. At this time measurements for body mass, shoulder height from the floor and arm segment lengths will be taken. One week after this initial test, in the Physical Activity Complex gymnasium, you will complete your training for half an hour a day on five consecutive days. You will be videotaped shooting free throws from a wheelchair, and will be provided with feedback based on which group you are placed in. One week after the training, you will come back to the Physical Activity Complex gymnasium for a retention test. You will be videotaped shooting free throws from a wheelchair without any feedback. This session will take approximately 5 minutes.

Research Subject Responsibilities: If you agree to participate in this study, you will be required to avoid playing basketball or wheelchair basketball for the duration of the study.

Risks and Discomforts: Participating in the study could lead to some muscle soreness in the dominant arm. This will be minimized by including a warm-up prior to the training and testing sessions. There may be unforeseen risks during the study or after it is completed.

Confidentiality: While absolute confidentiality cannot be guaranteed, every effort will be made to ensure that the information you provide for this study is kept entirely confidential. Your name will not be attached to any information, nor mentioned in any study report, nor be made available to anyone except the research team. It is the intention of the research team to publish results of this research in scientific journals and to present the findings at related conferences and workshops, but your identity will not be revealed. The video taken during the course of the study will be accessible only to the researchers and will be identified only by your assigned study number.

Research-Related Injury: There will be no costs for you for participation in this study. In the event that you become injured as a result of participating in this study, necessary medical treatment will be made available at no additional cost to you. By signing this document you do not waive any of your legal rights.

Benefits of Study Participation: This study may result in an improvement in your basketball shooting ability, but this benefit is not guaranteed. We hope that the information learned from this study can be used in the future to benefit other people.

Voluntary Withdrawal: Your participation in this research is entirely voluntary. You may withdraw from this study at any time. If you decide to enter the study and to withdraw at any time in the future, there will be no penalty.

If you choose to enter the study and then decide to withdraw at a later time, all data collected about you during your enrollment in the study will be retained for analysis.

Withdrawal Initiated by the Investigator: If you do not follow the instructions of the study investigators or fail to keep appointments, the study investigators may withdraw you from the study.

The study investigators may decide to discontinue the study at any time, or withdraw you from the study at any time, if they feel that it is in your best interests.

Who to contact for questions about the study: If you have any questions about this study or desire further information about this study before or during participation, you can contact Brianne Hamilton at (306) 373-1229 or Dr. Eric Sprigings at (306) 966-1077.

Who to contact for questions or concerns about a person's rights as a research subject: If you have any questions about your rights as a research subject or concerns about the study, you should contact the Chair of Biomedical Research Ethics Board, c/o the Office of Research Services, University of Saskatchewan at (306) 966-4053.

Payment, Honoraria, and Reimbursement: None

Alternatives to the study:
You do not have to participate in this study to improve your basketball free-throw shooting ability. For example, you could hire a coach or join a basketball team in the community with whom you could practice to improve your shooting ability.

Consent to Participate: I, ________________________ have read and understood the description provided above; I have been provided with an opportunity to ask questions and my questions have been answered satisfactorily. I consent to participate in the study described above, understanding that I may withdraw at any time. I understand that I am not waiving any of my legal rights as a result of signing this consent form. A copy of this consent form has been given to me for my records.

I give permission for the video and still frames from the video to be used under the following conditions only:

as raw data, not to be viewed outside of the research team (researcher, and supervisor)

Yes ☐ No ☐

for educational purposes (professional and research presentations) and research publications. If you agree to this, others may be able to identify you in pictures and video used in research presentations and publications.

Yes ☐ No ☐

________________________________ ________________________________
Signature of participant Date

________________________________ ________________________________
Signature of researcher Date

APPENDIX C

COVER LETTER AND CONSENT FORM FOR PARTICIPANTS IN THE PILOT STUDY

Consent Form
Part 2

Title: Using optimized computer simulation to facilitate in the learning of the free throw in wheelchair basketball

Investigators:
Brianne Hamilton, B.Sc.(Kin). Graduate Student, College of Kinesiology, Physical Activity Complex, University of Saskatchewan (373-1229)
Dr. Eric Sprigings, Ph.D., Professor (Supervisor), College of Kinesiology, Physical Activity Complex, University of Saskatchewan (966-1077)

Introduction: You are being invited to participate in this research study examining the learning of the free throw in wheelchair basketball. The study will include shooting free throws from a wheelchair while being videotaped.

Voluntary Participation: Your participation is entirely voluntary, so it is up to you whether or not to take part in this study. Before you decide, it is important for you to understand what the research involves. This consent form will tell you about the study, why the research is being done, what will happen during the study and the possible benefits, risks, and discomforts

If you wish to participate, you will be asked to sign this form. If you decide to take part in this study, you are still free to withdraw at any time, without giving any reasons for your decision, and without any penalty of any sort.

If you do not wish to participate, you do not have to provide any reason for your decision not to participate.

Purpose and Objectives of the Study: The purpose of the study is to examine whether the knowledge of an optimal movement pattern will help improve free throw shooting skills in wheelchair basketball to the same extent in people who do and do not use wheelchairs. We hypothesize that there will be no significant difference in the number of successful free throws for people who do and do not use wheelchairs after they are given knowledge of an optimal movement pattern.

Procedures:
Inclusion and Exclusion criteria: In order to be included in the study, you must have the functional ability of a player classified as 3 to 4.5 on the International Wheelchair Basketball Federation classification system, as determined by a trained classifier. This means that you will be able to maintain your trunk stability while your arms are extended over your head. You must also be able to throw the basketball the distance from the free throw line to the backboard of the basketball hoop while seated in a wheelchair. You will be excluded if you have any conditions affecting upper body strength or flexibility, or any dominant arm or shoulder injury or pain

If you agree to participate in this study, the following will happen:

You will shoot free throws while seated in a wheelchair, and will be periodically shown video of yourself shooting the free throws with a personalized optimal movement superimposed over the video. You will be compared to a group of people who do not use wheelchairs who are involved in the same study and doing the same training as yourself.

The study will take place over a three week period. Initially, you will complete a preliminary (i.e. “baseline”) test, which will take approximately 30 minutes. For this initial test, you will arrive at the Physical Activity Complex gymnasium and will be videotaped shooting free throws from a wheelchair. At this time measurements for body mass, shoulder height from the floor and arm segment lengths will be taken. Body mass will be estimated using your arm mass, which will be measured by hanging your arm in a sling that is suspended from a scale. One week after this initial test, in the Physical Activity Complex gymnasium, you will complete your training for half an hour a day on three days. You will be videotaped shooting free throws from a wheelchair, and be periodically shown video of your previous free throws with a personalized optimal movement superimposed over the video. One week after the training, you will come back to the Physical Activity Complex gymnasium for a retention test. You will be videotaped shooting free throws from a wheelchair without any feedback. This session will take approximately 5 minutes.

Risks and Discomforts: Participating in the study could lead to some muscle soreness in the dominant arm. This will be minimized by including a warm-up prior to the training and testing sessions. There may be unforeseen risks during the study or after it is completed.

Confidentiality: While absolute confidentiality cannot be guaranteed, every effort will be made to ensure that the information you provide for this study is kept entirely confidential. Your name will not be attached to any information, nor mentioned in any study report, nor be made available to anyone except the research team. It is the intention of the research team to publish results of this research in scientific journals and to present the findings at related conferences and workshops, but your identity will not be revealed. The video taken during the course of the study will be accessible only to the researchers and will be identified only by your assigned study number.

Research-Related Injury: There will be no costs for you for participation in this study. In the event that you become injured as a result of participating in this study, necessary medical treatment will be made available at no additional cost to you. By signing this document you do not waive any of your legal rights.

Benefits of Study Participation: This study may result in an improvement in your basketball shooting ability, but this benefit is not guaranteed. We hope that the information learned from this study can be used in the future to benefit other people.

Voluntary Withdrawal: Your participation in this research is entirely voluntary. You may withdraw from this study at any time. If you decide to enter the study and to withdraw at any time in the future, there will be no penalty.

If you choose to enter the study and then decide to withdraw at a later time, all data collected about you during your enrollment in the study will be retained for analysis.

Withdrawal Initiated by the Investigator: If you do not follow the instructions of the study investigators or fail to keep appointments, the study investigators may withdraw you from the study.

The study investigators may decide to discontinue the study at any time, or withdraw you from the study at any time, if they feel that it is in your best interests.

Who to contact for questions about the study: If you have any questions about this study or desire further information about this study before or during participation, you can contact Brianne Hamilton at (306) 373-1229 or Dr. Eric Sprigings at (306) 966-1077.

Who to contact for questions or concerns about a person's rights as a research subject: If you have any questions about your rights as a research subject or concerns about the study, you should contact the Chair of Biomedical Research Ethics Board, c/o the Office of Research Services, University of Saskatchewan at (306) 966-4053.

Payment, Honoraria, and Reimbursement: None

Alternatives to the study:
You do not have to participate in this study to improve your basketball free-throw shooting ability. For example, you could hire a coach or join a wheelchair basketball team in the community with whom you could practice to improve your shooting ability.

Consent to Participate: I, ______________________ have read and understood the description provided above; I have been provided with an opportunity to ask questions and my questions have been answered satisfactorily. I consent to participate in the study described above, understanding that I may withdraw at any time. I understand that I am not waiving any of my legal rights as a result of signing this consent form. A copy of this consent form has been given to me for my records.

I give permission for the video and still frames from the video to be used under the following conditions only:

as raw data, not to be viewed outside of the research team (researcher, and supervisor)

Yes ☐ No ☐

for educational purposes (professional and research presentations) and research publications. If you agree to this, others may be able to identify you in pictures and video used in research presentations and publications.

Yes ☐ No ☐

______________________________ ________________________
Signature of participant Date

______________________________ ________________________
Signature of researcher Date

APPENDIX D

RESEARCH ADEVERTISEMENT

BASKETBALL RESEARCH STUDY

Males without physical disabilities affecting upper body strength or flexibility are needed for a research study on the free throw in wheelchair basketball at the College of Kinesiology, University of Saskatchewan. This study will examine the effects that visual feedback from an optimal computer simulation has on the shooting success of free throws in wheelchair basketball. If you are 18 or older, and do not have any conditions affecting upper body strength or flexibility, any arm or shoulder injury or pain, are not currently participating in basketball at any level, or have less than 2 years of previous participation in basketball, you are eligible to participate.

The training will require approximately 30 minutes/day for 3 days. In addition, a 10 minute pre-test will be completed one week prior to training, and a 5 minute retention test will be completed one week after training. All testing will take place at the College of Kinesiology. Benefit from training is not guaranteed.

To participate in this wheelchair basketball research project, call Brianne Hamilton at 373-1229 or email bns460@mail.usask.ca

APPENDIX E

MEASUREMENTS OF PARTICIPANTS IN OPTIMAL PATTERN AND EXPERTS FROM THE PILOT STUDY

participant	group	body weight	upper arm	lower arm	hand	shoulder height
participant #1	Treatment	69.5 kg	.32 m	.27 m	.17 m	1.13 m
participant #2	Treatment	93.0 kg	.35 m	.25 m	.15 m	.99 m
participant #6	Treatment	78.3 kg	.34 m	.28 m	.14 m	1.05 m
participant #14	Treatment	96.5 kg	.33 m	.28 m	.15 m	1.06 m
participant #18	Treatment	98.8 kg	.35 m	.29 m	.16 m	1.05 m
participant #20	Treatment	79.4 kg	.33 m	.26 m	.15 m	1.02 m
participant #21	Treatment	56.7 kg	.33 m	.25 m	.15 m	.99 m
participant #23	Treatment	70.3 kg	.34 m	.26 m	.16 m	1.03 m
participant #28	Treatment	81.4 kg	.37 m	.30 m	.16 m	1.05 m
participant #29	Treatment	87.5 kg	.36 m	.29 m	.16 m	1.02 m
participant #31	Treatment	114.8 kg	.33 m	.31 m	.14 m	1.02 m
participant #34	Expert	76.2 kg	.31 m	.26 m	.16 m	1.20 m
participant #35	Expert	75.7 kg	.34 m	.29 m	.14 m	1.15 m
participant #36	Expert	66.2 kg	.29 m	.24 m	.15 m	1.16 m
participant #37	Expert	93.6 kg	.32 m	.30 m	.15 m	1.19 m